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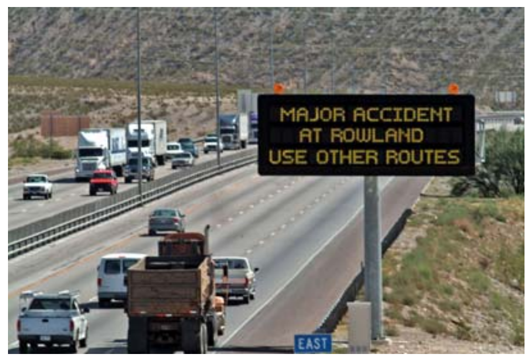
White Paper: Impacts of Using Dynamic Features to Display Messages on Changeable Message Signs



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WHITE PAPER:
IMPACTS OF USING DYNAMIC FEATURES TO DISPLAY MESSAGES ON CHANGEABLE MESSAGE SIGNS

INTRODUCTION

There are three types of dynamic changeable message sign (CMS) message display modes that are sometimes used by some departments of transportation (DOTs). These are:

- Flashing an entire one-phase, three-line message;
- Flashing one line of a one-phase, three line message; and
- Alternating one line of a two-phase, three-line message while keeping the other two lines constant.

Some state DOT personnel have speculated that continuously flashing certain one-phase messages (typically those that describe significant traffic disruptions downstream) or flashing one line of a one-phase message (typically the top problem statement line) emphasizes that the message is especially important to drivers and should be heeded. However, it was not clear whether such practices have any adverse effects on message reading times, driver comprehension, and driver performance in comparison to displaying the CMS message in a static mode.

Another operating practice by some DOTs is to format a two-phase message in such a way that the top two lines of the message remain constant and a third (bottom) line is alternated between two separate message line phrases. In essence, the CMS operates as if displaying a two-phase message, although only the bottom line actually changes. For this particular display practice, there was a need to determine whether drivers actually notice that the line changes. Also, it was not totally clear what effect the redundancy of information (top two lines repeated in each phase) has on driver reading times and comprehension of the entire message. For example, do the repeated lines cause drivers to read these lines more than once, thus increasing reading times?

Because of the various concerns associated with the dynamic message display practices in use in some jurisdictions, it was important to objectively determine whether such practices:

- Affect the amount of time it takes a driver to read the message.
- Affect a driver's ability to properly comprehend the message.
- Are preferred by drivers in comparison to static or non-redundant messages.
- Affect driver performance.

REPORTED RESEARCH

Two studies were conducted to address these issues. The first was a laboratory study conducted by the Texas Transportation Institute (TTI) in Texas in 2000. The second was a driving simulator study also conducted by TTI and reported in 2005. Each of the three dynamic message modes were evaluated and compared with an alternative message mode. Flashing or flashing line messages were compared with comparable static messages. Alternating one line two-phase, three-line messages with redundancy were compared with two-phase messages without redundancy. Examples of the three dynamic message modes with their matching comparison message modes are shown in Table 1.

Table 1. Examples of Test Messages

Flash	Static
MAJOR ACCIDENT **AT TIDWELL** **3 LANES CLOSED**	MAJOR ACCIDENT AT TIDWELL 3 LANES CLOSED

Flash Line	Static Line
FREEWAY CLOSED AT COLLEGE ST FOLLOW DETOUR	FREEWAY CLOSED AT COLLEGE ST FOLLOW DETOUR

Alternating Line with Redundancy	No Alternating Line without Redundancy
CONSTRUCTION AT BROADWAY RD **ALL LANES CLOSED**	CONSTRUCTION AT BROADWAY RD
CONSTRUCTION AT BROADWAY RD **USE OTHER ROUTES**	ALL LANES CLOSED USE OTHER ROUTES

Note: Bold in the message indicates the portion of the message that flashes or alternates

Dudek et al. in 2000 (*1*) and Dudek and Ullman in 2002 (*2*) reported on research that was conducted for the Texas Department of Transportation (TxDOT) as part of a study to improve CMS messages and operations in Texas. Traffic management center managers in several TxDOT districts were interested in knowing more about the effectiveness of using some of the dynamic features of CMSs.

Single-task human factors studies were conducted in five cities (Dallas, El Paso, Fort Worth, Houston, and San Antonio) using laptop computers. The laboratory instrument was administrated to 260 individuals, 52 from each of the five study locations, and matched as much as practical to the Texas driving population based on age, education, and gender. Although some important findings were reported, the study was a single-task experiment. Subjects were not placed under any type of additional mental workload in order to mimic the attention and information processing demands of driving on freeways. Thus, the transferability of the results to actual driving situations could not be fully ascertained in that study.

Subsequent driving simulator studies were conducted in College Station, Texas, and reported by Dudek et al. in 2005 (*3*). The research was conducted as part of the Traffic Management Center Pooled-Fund Study administered by the Federal Highway Administration. A total of 64 subjects from the Bryan–College Station area participated in the study. The sample matched as much as practical the Texas driving population based on age, education, and gender. The "driving" scene chosen for the study was a six-lane freeway with primarily tangent sections and slight horizontal curvature. In addition to "driving" the vehicle on the freeway, additional driver workload was introduced via an additional car-following task. Each subject closely followed a selected vehicle that varied its speed significantly prior to, during, and immediately after the display of a CMS message. The speed of the lead vehicle varied significantly at other times during each study session to minimize the possibility that subjects would associate lead vehicle speed changes with the display of a CMS message.

In addition to reading time, comprehension, and preferences, the following subject driving performance measures were evaluated: acceleration noise (the standard deviation of acceleration), average lane position, standard deviation of lane position, maximum distance headway, minimum distance headway, average distance headway, and standard deviation of distance headway.

SUMMARY OF RESEARCH FINDINGS

Effects of Flashing One-Phase, Three-Line Messages

Findings—Previous Laboratory Study

The results of the computer laptop laboratory study were as follows:

1. Flashing a one-phase, three-line message increased the amount of time required to read the message by approximately 17 percent. The average reading time for the flashing message was 10.1 s in comparison to 8.6 s for the static message. The difference was statistically significant ($\alpha = 0.05$).

2. Flashing the message had no significant effect upon subject comprehension of the information being presented.

3. Subject preferences were evenly split between flashing and static messages.

Findings—Driving Simulator Study

The results of the driving simulator studies were as follows:

1. No significant differences were found in average reading time between flashing messages and static messages. The average reading time for both was 7.2 s.

2. No significant differences were found in average reading times among age groups, education levels, or gender.

3. The results suggest that flashing messages may have adverse affects on message understanding for drivers who are unfamiliar with this mode of CMS display. Only 78 percent of the subjects understood the bottom line of the flashing messages when first exposed to this type of dynamic display. The second time the subjects saw this type of

display, correct comprehension rates increased to 95 percent. The percent difference was statistically significant (α = 0.05).

4. Overall, comprehension of each message line was at very acceptable levels of 87 percent or higher for both the flashing and the static messages. There were no significant differences in comprehension between the flashing and static messages.
5. Overall, 80 percent of the subjects understood all three lines of the flashing messages and 88 percent understood all three lines of the static messages. However, there was again some evidence that subjects familiar with the experiment and message displays were better able to understand both types of messages as compared to the subjects who were unfamiliar with the displays. These results indicate possible learning effects, and further support the notion that unfamiliar drivers may have some difficulty in reading all three lines of flashing messages while driving at typical freeway speeds.

6. Only 40 percent of the subjects preferred the flashing message, while 60 percent preferred the static message mode. The difference was statistically significant (α = 0.05). The most common reason cited by the subjects who preferred the flashing message mode was that it gets the attention of drivers (as hypothesized by some state DOT personnel). Conversely, the most common reasons for those who preferred a static message was that it gives the driver more time to read the message and it is easier to read, perceptions which were largely validated in the reading time and comprehension results.

7. No differences were found between the flashing messages and the static messages with respect to the subject performance measures of acceleration noise, lane position, standard deviation of lane position, average distance headway or standard deviation of distance headway.

Strictly speaking, the results of the driving simulator study differed from those of the computer laptop laboratory study. In the computer laptop study, average reading times for the flashing messages were found to be significantly longer than for the static messages, whereas the results of the driving simulator study showed reading times to be identical. With regards to motorist comprehension of the messages, the findings of the driving simulator study indicated that unfamiliar drivers would be adversely affected by flashing messages. The effects on unfamiliar drivers were not evaluated in the computer laptop laboratory study. Finally, in contrast to the computer laptop study in which the subjects were evenly split as to which display format they preferred, a significantly higher percentage of subjects in the driving simulator results preferred the static messages. A summary of the findings is shown in Table 2.

Table 2. Flashing CMS Messages

Measure of Effectiveness	Computer Laptop Studies	Driving Simulator Studies
Reading Time	Longer than static message*	Same as static message
Comprehension	Same as static message	Familiar drivers: same as static message Unfamiliar drivers: lower than static message*
Preference	Same as static message	Most preferred static message*
Driving Performance	N/A	Same as static message

* Significant at α = 0.05
N/A = Not applicable

Implications of Findings

The results of the two studies were mixed. However, the fact that the average reading time for the flashing message was significantly longer than for the static message and that the comprehension for unfamiliar drivers was lower during the driving simulator study, suggests that flashing messages should not be recommended at this time. However, further research should be performed to validate this recommendation.

Effects of Flashing One Line (Top Line) of One-Phase, Three-Line Messages

Findings—Previous Laboratory Study

In the computer laptop laboratory study, flashing one line (top line) of one-phase, three-line messages containing three units of information produced the following results:

1. Flashing one line of a one-phase, three-line message significantly increased the average reading time. The average reading time for the flashing line messages was 11.0 s in comparison to 9.2 s for the static messages, an increase of 20 percent. The difference was statistically significant ($\alpha = 0.05$).

2. Flashing one line reduced the ability of subjects to remember parts of the message that were not flashing. Specifically, the percent of subjects who could correctly recall the last line of the flashing line messages was significantly lower than for the corresponding static messages ($\alpha = 0.05$).

3. Subject preferences were fairly evenly split between the flashing line and the static messages.

Findings—Driving Simulator Study

The findings of the diving simulator study relative to flashing the top line of a one-phase, three line message containing three units of information are listed below.

1. The average reading time for the flashing line message was found to be 0.7 s longer for the flashing line messages than the static messages (7.8 vs. 7.1 s). This result suggests that reading time may increase by nearly 10 percent when a message line is flashed in a one-phase message.

2. No significant differences were found in average reading times among age groups, education levels, or gender.

3. Similar to what was observed when the entire three-unit message was flashed, these results suggest that flashing a message line will have adverse effects on message understanding for unfamiliar drivers. It may also adversely affect familiar drivers but to a lesser degree. Overall, the percent of subjects that understood the bottom line (75 percent) was significantly lower than for the top and middle message lines (91 percent) when the top line of the message was flashed.

4. Overall, only 62 percent of the subjects recalled all three lines of the flashing line message, compared to 71 percent of subjects who recalled all three lines of the static messages. There was a significant increase in the percent of subjects that understood all three message lines between the familiar and unfamiliar subjects, again indicating learning between the two experiments and the effects that flashing line messages may have on unfamiliar drivers.

5. The subjects were evenly split (50/50) in their preference between the flashing line and static message modes. Subjects who preferred the flashing line message did so because they felt it was better able to get their attention or emphasized the importance of the information. Conversely, those who preferred the static message indicated that the flashing line was distracting and the static message gave them more time to read the message and was easier to read.

6. No differences were found between the flashing messages and the static messages with respect to acceleration noise, lane position, standard deviation of lane position, average distance headway or standard deviation of distance headway.

In summary, the findings with respect to reading times, comprehension, and preference between the computer laptop laboratory and driving simulator studies were consistent. Table 3 contains a summary of both studies.

Table 3. Flashing Line CMS Messages

Measure of Effectiveness	Computer Laptop Studies	Driving Simulator Studies
Reading Time	Longer than static message*	Longer than static message*
Comprehension	Lower than static message	Familiar drivers: lower than static message Unfamiliar drivers: lower than static message*
Preference	Same as static message	Same as static message
Driving Performance	N/A	Same as static message

* Significant at $\alpha = 0.05$
N/A = Not applicable

Implications of Findings

The consistent findings between the laboratory and driving simulator studies with respect to longer average reading time and lower comprehension for the flashing line messages , supports the adoption of an MUTCD standard that flashing line message shall not be used.

Effects of a Two-Phase, Three-Line Message with an Alternating Line and Information Redundancy between Phases

Findings—Previous Laboratory Study

In the computer laptop laboratory studies, evaluation of the effects of alternating one line (bottom line) of text and keeping the other two lines constant on a two-phase, three-line message resulted in the following:

1. The average reading time for the alternating line messages was significantly longer (approximately 21 percent) than for comparable two-phase messages without redundancy. The average reading time for the redundant message was 16.2 s in comparison to 13.4 s for the messages without redundancy. The difference was statistically significant ($\alpha = 0.05$).

2. The redundant messages did not reduce the ability of subjects to remember other parts of the messages.

3. Subject preferences were fairly evenly split between having and not having redundant information in both phases.

Findings—Driving Simulator Study

The findings from the driving simulator study are listed below.

1. The average reading time for the alternating line message with redundancy and non-alternating line message without redundancy were 15.9 and 14.1 s, respectively—a difference of 1.8 s (13 percent). The difference is significant ($\alpha = 0.05$).

2. No significant differences were found in average reading times among age groups, education levels, or gender.

3 No difference in comprehension was found between the messages with redundancy and the messages without redundancy.

4. No statistically significant differences were found in the number of message lines recalled by the subjects between the messages with redundancy and messages without redundancy. However, the percent of subjects that recalled all four message lines was very low in both cases. Only 65 and 68 percent of subjects recalled all four message lines for the message with redundancy and without redundancy.

6. Fifty-nine percent of the subjects preferred the message with redundancy and 41 percent preferred the message without redundancy. The difference was statistically different ($\alpha = 0.05$). Interestingly, the average reading time for the message with redundancy was almost two seconds longer than the messages without redundancy.

7. Some of the subjects who preferred the message with redundancy felt that it provided more information at one time, the critical (to them) information remained static, and it

was easier to process the information. On the other hand, some subjects who preferred the message without redundancy felt it was easier to read and process and was easier to notice the message change between phases.

8. No differences were found between the flashing and static messages with respect to acceleration noise, lane position, standard deviation of lane position, average distance headway or standard deviation of distance headway.

In summary, there were no differences between the computer laptop laboratory study and the driving simulator study with one exception. A higher percentage of the subjects preferred the redundant messages in comparison to the non-redundant messages. The difference is significant ($\alpha = 0.05$). A summary of the laboratory and driving similar studies is given in Table 4.

Table 4. Alternating Line with Redundancy CMS Messages

Measure of Effectiveness	Computer Laptop Studies	Driving Simulator Studies
Reading Time	Longer than non-redundant message	Longer than non-redundant message*
Comprehension	Same as non-redundant message	Same as non-redundant message
Preference	Same as static message	Higher than static message*
Driving Performance	N/A	Same as static message

* Significant at $\alpha = 0.05$
N/A = Not applicable

Implications of Findings

The significantly longer average reading times for the alternating line message with redundancy during both the computer laptop laboratory study and the driving simulator study supports the adoption of an MUTCD standard that this dynamic mode shall not be used.

RECOMMENDED ADDITIONS TO THE MUTCD

The wording below is recommended for the MUTCD based on the results of the state-of-knowledge. Note that the terms used in the recommendations are consistent with a new MUTCD Part and Chapters previously prepared and submitted to FHWA by Dudek (*4*). Furthermore, it should be noted that the recommendations apply to incident and roadwork messages displayed on large permanent CMSs. Messages displayed on Portable CMSs are much shorter than those displayed on permanent CMSs and thus the results of the findings do not necessarily apply to PCMSs.

Guidance

A flashing message display format should not be used on Variable CMSs.

Standard

Flashing display formats that include flashing one or two lines of a message shall not be used on Variable CMSs.

Standard

An alternating line message is defined as a two-phase message in which the information on one of the lines changes between the two phases while the information on the other two lines remain the same. Alternating line messages shall not be used on Variable CMSs.

REVISED MODULE 9 OF THE GUIDELINES FOR CHANGEABLE MESSAGE SIGN MESSAGES REPORT

One of the tasks of the current study was to update Module 9 of the technical report titled *Guidelines for Changeable Message Sign Messages* that was prepared as part of previous Traffic Management Pooled-Fund Study, and incorporate the findings of the driving simulator study. The update to Module 9 is shown in the Appendix.

SUMMARY AND RECOMMENDATIONS

Recommendation and Rationale

The results of the computer laptop laboratory study and driving simulator study for the flashing line and alternating line message modes were consistent. However, there were differences for the messages in which all three lines flashed, particularly with respect to reading time. In the laboratory study, the flashing messages resulted in a significantly longer reading time than for the static messages. In contrast, no differences in reading time were found in the driving simulator study. This latter result suggests that further research should be conducted to better resolve the disagreement in reading time for the flashing message. In addition, the studies to date have focused exclusively on the potential adverse effects of dynamic displays. No attempts have been made to assess whether the perception by some subjects and state DOT personnel that the dynamic features increase the attention-getting value of the message above and beyond that possible with the use of static messages actually occurs. The authors of this report recommend that FHWA initiate proving ground studies to further the knowledge on the effects of the flashing three lines of a one-phase, three line messages. It is also recommended that, although there was consistency between the laboratory and driving simulator studies for the flashing line and alternating line message modes, added value can be gained at a low cost to further evaluate these modes in proving ground studies. The rationale for conducting proving ground studies is addressed in the following paragraphs.

The current study was conducted using the TTI Driving Simulator in College Station, Texas. No differences were found in driving performance between each of the dynamic display features and its comparable static display. The reading time, comprehension, and preference results of the driving simulator study with respect to all three dynamic feature evaluated compare favorably to those from the computer laptop study, with only a few exceptions that were associated with the flashing three-line, one phase messages. Although average reading times for the flashing messages were found to be significantly longer than for the static messages in the computer laptop study, the results of this driving simulator study showed reading times to be nearly identical. Also, in contrast to the driving simulator results which show a significant preference for static (non-flashing messages), subjects in the Texas study were evenly split as to which display format they preferred.

An important feature of driving simulators is that they provide an environment in which the actions taken by the subjects (i.e., steering, braking, etc.) replicate the typical actions taken by drivers in the real world. They also provide opportunities to introduce secondary task-loading into the studies. After evaluating several alternative approaches for secondary task loading in the current study, the decision was made in concert with FHWA that the best approach within the capabilities of the TTI Driving Simulator was to use the car-following technique discussed earlier in the report.

One factor that may have influenced the results of the driving simulator study was the very high attention that subjects devoted to the vehicle that they were following. Because of the high mental and visual concentration on the lead vehicle so that the subject would maintain a safe driving distance, most subjects totally ignored the roadside features in the surrounding simulated environment. In addition, the operational responses were highly constrained because the subjects did not have to change lanes and follow curves during the experiments. In essence, the study design eliminated potential operational MOEs that could have been measured.

The level of agreement shown between the computer laptop and the driving simulator studies has shown that subject visual and mental concentration similar to the current driving simulator study can be achieved with laboratory studies using laptop computers with secondary workload activities. This gives rise to speculation that laptop studies with secondary task loading features may be an effective means of conducting similar studies in different locations in the U.S.

For any study, it is important to understand how well the results represent the real world. Depending on the question of interest to be answered through research, there is a hierarchy of human factors studies that can be performed with each level resulting in different levels of knowledge with respect to translation of the results to the real world. The hierarchy of human factors studies with respect to CMS signing issues is as follows:

- Surveys and focus group studies.
- Basic laboratory studies.
- Single-task laptop laboratory studies.
- Driving simulator and secondary task-loading laptop studies.

- Proving ground studies.
- Controlled field studies.
- Real world event studies.

Surveys and focus group studies provide basic subjective information about information that might be considered in CMS messages. Basic laboratory studies can provide useful information to separate the "worst" cases or designs from further consideration but do not have the resolution to compare all alternatives. Single-task laptop laboratory studies allow the researchers to make comparisons among alternative designs. However, specific values (e.g., reading times) may differ from the real world.

In the next order in the hierarchy of studies are driving simulator and laptop studies with secondary task loading of subjects. Both types of studies introduce secondary loading and provide opportunities to compare alternatives during higher subject workload with greater resolution. However, specific values (e.g., reading times) may still differ from the real world. Thus, the reading time values found in the current driving simulator study allow one to compare the differences between the alternatives, but in no way indicate that the same values (e.g., reading times) would be the same in the real world. One limitation of a driving simulator study is that residents from only one location are generally used in the sample. Regional differences cannot be measured unless driving simulators from other locations are used. Because each driving simulator has different features and software, the cost of replicating the experiment becomes very high. In contrast, regional differences can be easily and cost-effectively measured using laptop computers with secondary loading tasks. One limitation of laptop studies is that the specific actions that the subjects need to take (e.g., steering, braking, etc.) are not the same as would be required in a driving situation.

The next order in the hierarchy and thus capable of higher resolution with respect to translation to the real world are proving ground studies. Subjects actually drive a vehicle in a closed course and are asked to respond to certain situations or questions. The nature of the proving ground studies forces the subject to pay attention to the surrounding environment in contrast to what was experienced in the current driving simulator study. Eye-tracking can be included in the experiment so that differences in the amount of time subjects look at each CMS message and each line of the message. Missing from the proving ground environment is other traffic. Thus the subject's workload is less than the real world. However, this study approach allows the test administrators to control outside variables that might bias the results. Comparable to driving simulator studies, there is a high cost to replicate the experiment at other locations to measure regional differences.

Still higher on the hierarchy are controlled field studies in which each subject drives a vehicle on a highway. The subject responds to stimulus material (e.g., highway signs, CMS messages, etc.) by driving actions, or the subject answers questions asked by a test administrator after the subject passes the signs. In some studies the stimulus material can be introduced within the vehicle. The problem with this study method is that the environment changes frequently. That is, traffic may vary at the sign locations, or there may be traffic factors (e.g., lane changing, vehicles slowing, etc.) that constantly change. These outside influencing factors can adversely affect the results when alternative messages are being evaluated. Thus, the sample size has to be extremely large in order to collect sufficient data to account for the variances associated with the external influencing factors. Another factor to consider is that when the fictitious messages are displayed external to the vehicle they must be displayed on CMSs—an undesirable situation for most highway agencies.

The highest level is conducting studies on a highway and measuring the change in traffic characteristics in response to messages posted on CMSs. Similar to controlled field studies, the high variability of traffic during the course of the study would require very large samples. Also, fictitious messages must be displayed if direct comparisons and analyses are to be made. The cost of real world event studies would be prohibitively high. In addition, it would not be possible to gain insight on important characteristics such as reading times, comprehension, and preferences to compare the alternatives.

Proposed Research Study

A research problem statement designed as a follow-up to the current driving simulator study is described in the sections that follow.

Description

This project will build upon the results of the research completed under the TMC Pooled Fund Studies *Guidelines for Changeable Message Sign Messages* and *Impacts of Using Dynamic Features to Display Messages on Changeable Message Sign* projects. Several of the state DOTs that currently operate CMSs are using dynamic features in displaying messages. These dynamic features of displaying messages include: flashing an entire one-phase message; flashing one line or one word of a one-phase message; and alternating text on one line of a two-or-more-line CMS while keeping the other line(s) of text constant on the second phase of the message.

The results of previous laboratory and driving simulator studies for the flashing line and alternating line message modes were consistent. However, there were differences for the messages in which all three lines flashed, particularly with respect to reading time. In the computer laptop laboratory study, the flashing messages resulted in a significantly longer reading time than for the static messages. In contrast, no differences in reading time were found in the driving simulator study. This latter result suggests that further research should be conducted to resolve the disagreement in reading time for the flashing message.

Study Approach

Conduct proving ground studies to further evaluate the effects of the following three modes of dynamic message displays: 1) flashing an entire one-phase, three-line message, 2) flashing one line of a one-phase, three-line message, and 3) alternating one line of a two-phase, three-line message while keeping the other two lines constant. In previous studies, flashing line messages were evaluated with the top line flashing. In the proposed study, evaluations should be made of messages in which either the middle line or bottom line flashes. Also, alternating line messages should be evaluated in which the top line alternates (in contrast to the bottom line). Measures of effectiveness will include reading time, comprehension, preferences, and driving performance.

Deliverables

The products of this research effort will be a) a research report that contains documentation of the proving ground studies, and b) a White Paper that contains a summary of the major findings of the research in terms of preliminary guidance on the impacts of using dynamic features to display messages, recommended changes/additions to existing or proposed changes in the MUTCD, c) proposed text for the MUTCD. The intended audience for the deliverables is practicing traffic engineers.

Estimated Cost

The estimated cost for the project is $225,000.

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APPENDIX A
REVISED MODULE 9. DYNAMIC FEATURES ON CMSs

9.1 INTRODUCTION

Many CMSs have the capabilities to create dynamic features within a message. Two of the more common features being used by some TMCs are:

- Flashing a message or a line in a message, and
- Alternating lines in a two-phase message.

9.2 FLASHING MESSAGES OR LINES

Several state DOTs currently display CMS messages that flash or have one line that flashes in the belief that the features attract the attention of drivers and emphasize the importance of the message. Examples of these CMS features are shown below

ACCIDENT **AT ROWLAND** **USE ROUTE 46**

Flashing

ACCIDENT **AT ROWLAND** **USE ROUTE 46**

Flashing Line

Only a limited amount of research has been conducted on this topic, and the effects that flashing has on drivers while traveling on a freeway are not fully known. Dudek et al. and Dudek and Ullman (*1,2*) reported on single-task human factors laboratory studies that were conducted in Dallas, El Paso, Fort Worth, Houston, and San Antonio to initially examine whether the practice of flashing a one-phase message or one line in a one-phase, three-line message affects the amount of time it takes a driver to read and comprehend the message, or affects a driver's ability to comprehend the message. Follow-up driving simulator studies were conducted to gain greater insight on the effects of these dynamic CMS features while the subjects were under secondary work load (*3*).

Flashing One-Phase, Three-Line Messages

The results of the single-task study showed that in a laboratory setting, flashing one-phase, three-line messages did not adversely affect subject recall and comprehension to a significant degree in comparison to when the message was not flashed. However, the average reading times were significantly longer when the message was flashed. In contrast, for the driving simulator studies, the results indicated that unfamiliar drivers would have difficulty in understanding all parts of the entire message when it is flashed. In addition, no differences were found in average reading time between the flashing and static messages. This latter result suggests that further research should be conducted to resolve the disagreement in reading time for the flashing message. However, given that one of the two studies resulted in significantly longer reading time for the flashing message and lower comprehension levels for unfamiliar drivers, the use of the flashing dynamic mode cannot be recommended at this time

Flashing One Line of One-Phase, Three-Line Messages

Flashing one line of three-line messages significantly increased average reading time during both the laboratory and the driving simulator studies. In addition, comprehension levels were lower during both studies. The results strongly imply that CMS messages should not be displayed with single flashing lines.

9.3 ALTERNATING A LINE IN A TWO-PHASE MESSAGE

Another operating practice of interest is formatting a message in such a way that the top two lines remain constant and a third bottom line is changed on the second phase of a message. In essence the CMS operates as it were a two-phase message, but with information on two lines constant and redundant between the two phases. An example of a message with alternating text on one line of a three-line CMS while keeping the other two lines of text the same (redundant) is shown below.

ACCIDENT **AT ROWLAND** **USE ROUTE 46**	**ACCIDENT** **AT ROWLAND** **TUNE TO 530 AM**	*Alternating Line*

In both the laboratory study and the driving simulator study, two alternative styles of messages were. Examples of the two alternative messages styles evaluated are shown below.

CONSTRUCTION **AT ROWLAND** **ALL LANES CLOSED**	**CONSTRUCTION** **AT ROWLAND** **USE OTHER ROUTES**	*Alternating Line*
Phase 1	***Phase 2***	

Alternative 1: Message with redundancy

CONSTRUCTION **AT ROWLAND**	**ALL LANES CLOSED** **USE OTHER ROUTES**
Phase 1	***Phase 2***

Alternative 2: Message without redundancy

The results of the both studies indicated that alternating one line of text and keeping the other two lines constant did not adversely affect message recall. However, average reading times increased significantly. The subject preferences were evenly split between having and not having redundant information in both phases of the message. The results strongly imply that alternating line messages should not be displayed.

The alternating line approach has enticed personnel at some TMCs to display messages using formats that violate the principles presented in this *Manual*. Shown below are two messages that the author observed that illustrate how one can easily violate good formatting principles. As shown in the messages, the *Incident Location* message element was displayed on the first two lines followed by the *Incident Descriptor* and the *Lanes Affected* message elements—a violation of formatting principles presented in this *Manual*.

~~I-77 NORTH~~	*(Location)*	**~~I-77 NORTH~~**	*(Location)*
~~AT ROWLAND~~	*(Location)*	**~~AT ROWLAND~~**	*(Location)*
~~ACCIDENT~~	*(Incident Descriptor)*	**~~FREEWAY CLOSED~~**	*(Lanes Affected)*
Phase 1		***Phase 2***	

~~I-77 NORTH~~	*(Location)*	**~~I-77 NORTH~~**	*(Location)*
~~AT ROWLAND~~	*(Location)*	**~~AT ROWLAND~~**	*(Location)*
~~DUE TO ACCIDENT~~	*(Incident Descriptor)*	**~~2 RIGHT LANES CLOSED~~**	*(Lanes Affected)*
Phase 1		***Phase 2***	

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